Solve Hidden Maintenance Issues Using Testing and Balancing

By Rob Falke & Mel Johnson, National Comfort Institute

NCI National Comfort Institute, Inc.

2018 AHR EXPO CHICAGO JAN 22-24

National Balancing Council

About National Balancing Council & National Comfort Institute

At National Balancing Council (NBC), we have long known that true system performance and efficiency goes beyond traditional testing and balancing. NBC trained and certified professionals specialize in comprehensive HVACR system diagnostics. Technicians have the expertise to measure and verify *actual* system operating performance.

National Comfort Institute, Inc. (NCI) is the world leader in HVAC System Performance training and Air Balancing. We created the industry's best practices, processes, and forms and have been teaching them for decades. What makes NCI's approach different? We show you how to thoroughly test and diagnose the system using practical, easy-to-follow methods so you'll know exactly what to do to provide your customers with optimum comfort and energy efficiency. During the past two decades, NCI has trained and certified more than 25,000 HVAC industry professionals.

If You Don't Measure, You're Just Guessing™

About National Balancing Council & National Comfort Institute

The parent company to NBC, NCI has offices and staff in 10 states across the USA. NBC is the *only* large commercial certification that also includes training as part of the certification process. NCI is active in HVAC utility energy savings programs as well. We hope that you enjoy this presentation, and if you want to learn more:

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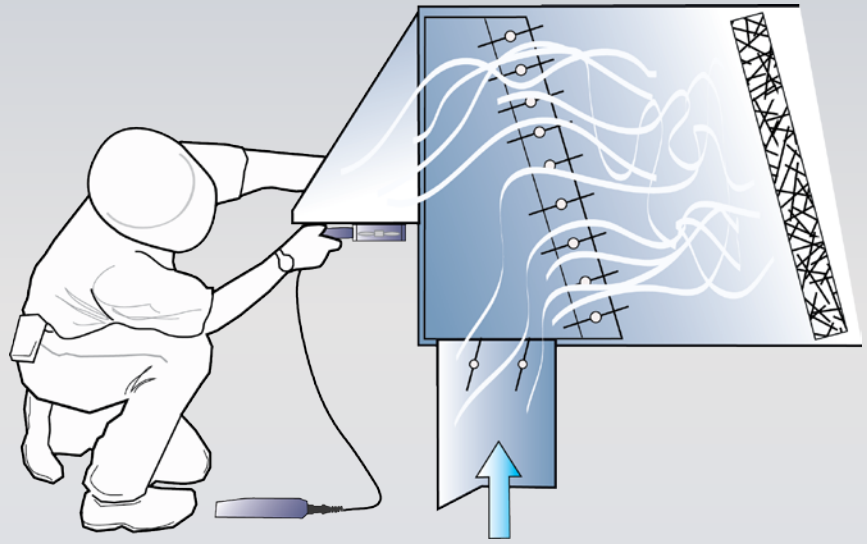
Solve Hidden Maintenance Issues Using Testing and Balancing

Learn to discover hidden defects in your systems

Mel Johnson and Rob Falke
National Comfort Institute



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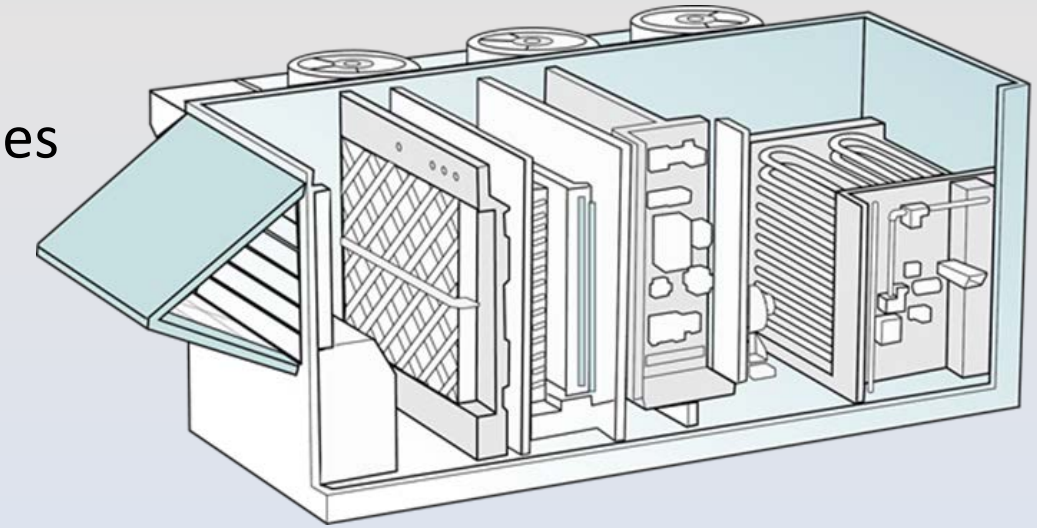
Mel Johnson Presentation Preview

Solve Hidden Maintenance Issues Using Testing and Balancing

- New trends in HVAC Maintenance
- Benchmarking with test and balance Key Performance Indicators
- Energy savings expectations of maintenance
- ASHRAE Standard 180 strengths and weaknesses
- Establish maintenance KPI reference values
- KPI's produce predicted maintenance opportunities
- Diagnose and solve maintenance problems



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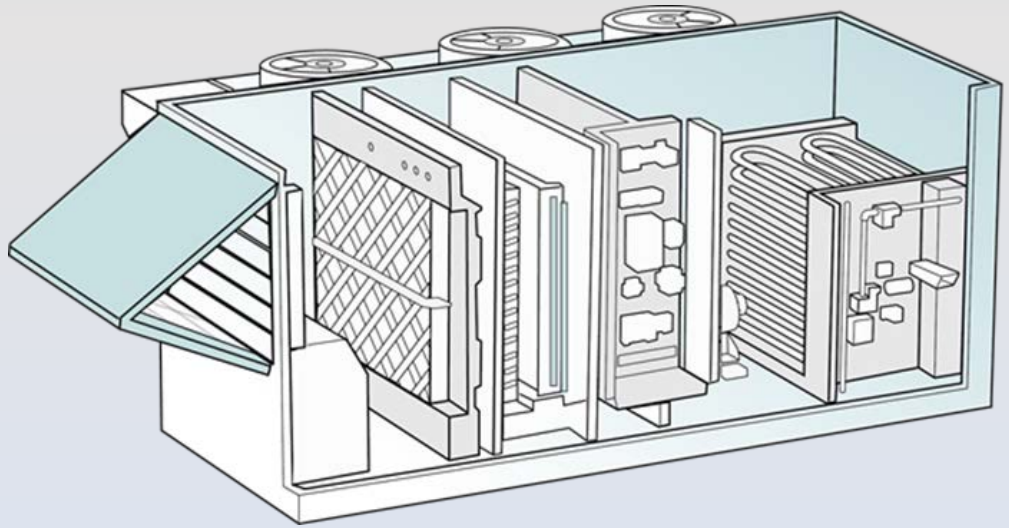
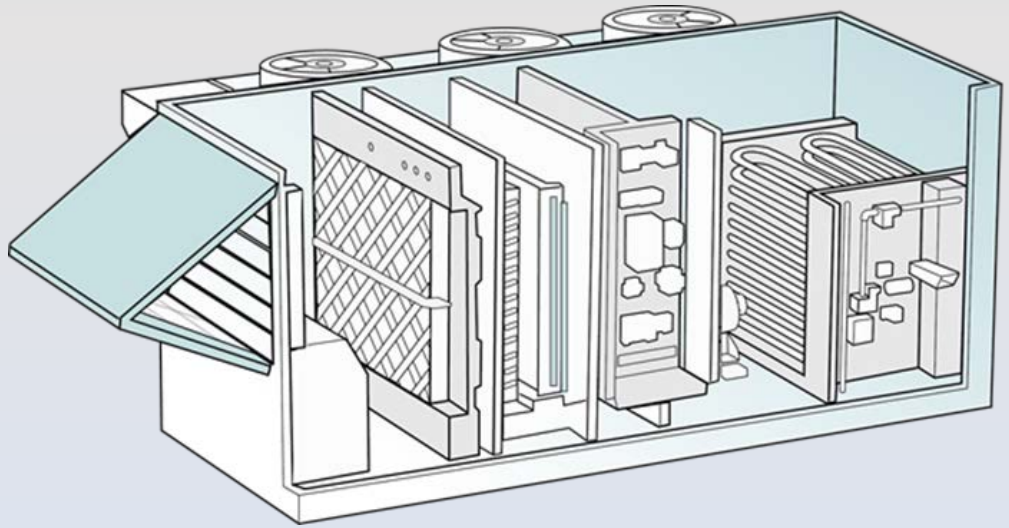
New trends in HVAC Maintenance

- Many Utility Energy Efficiency programs across the United States have deployed Refrigerant Charge Adjustment (RCA) as a energy savings measure as part of tune-up or maintenance programs
- It has been determined **other factors** impact the expected outcome of the charge adjustment referred to as non-RCA faults
- **“Addressing other non-RCA faults appears to be more beneficial than addressing the charge offset fault, itself”**



New trends in HVAC Maintenance

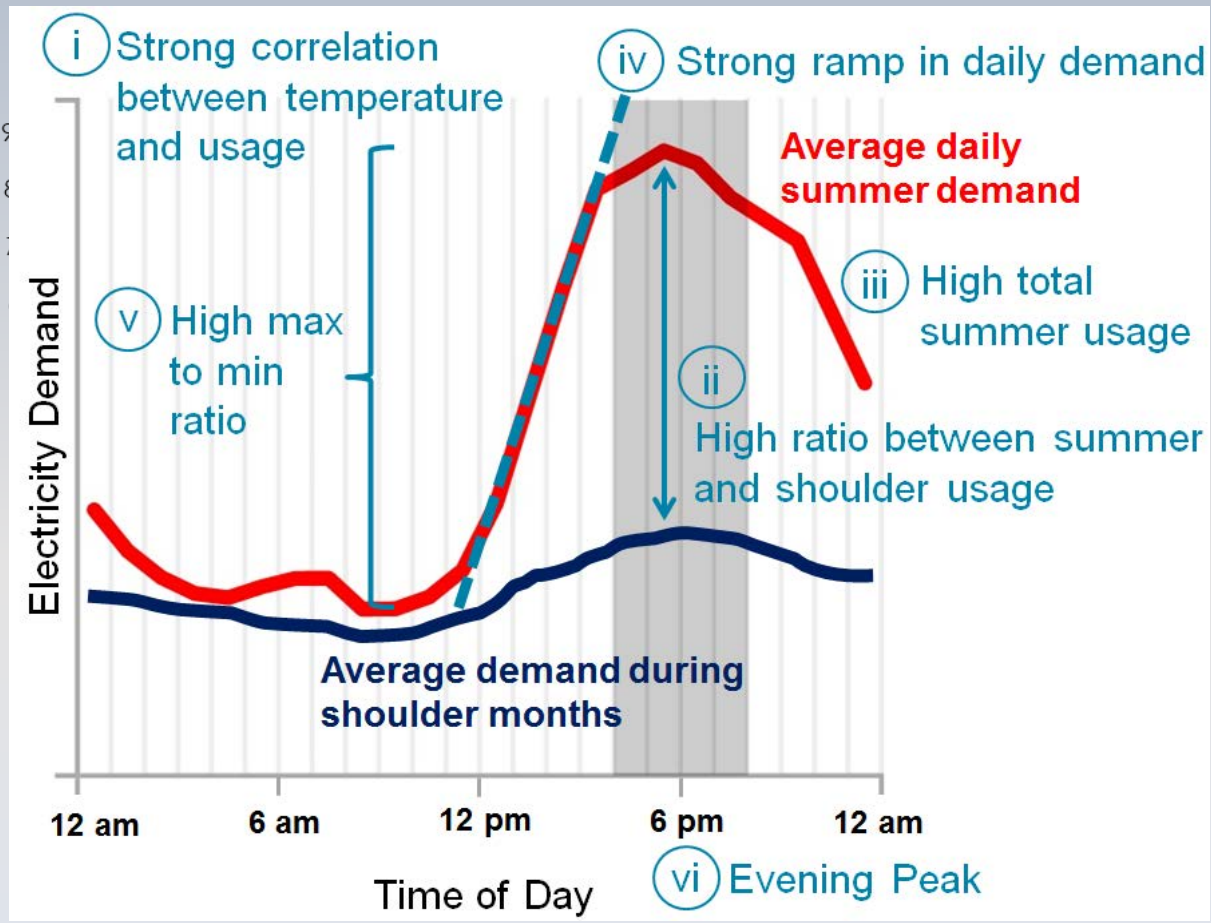
- What if maintenance programs simply produced measurable benefits that save energy and justify their cost?
- Currently, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) and key Industry Stakeholders are in the process of standardizing a test method to measure and score HVAC efficiency and performance in the field known as ASHRAE, SPC 221P



Energy savings is expected for customers with high savings potential

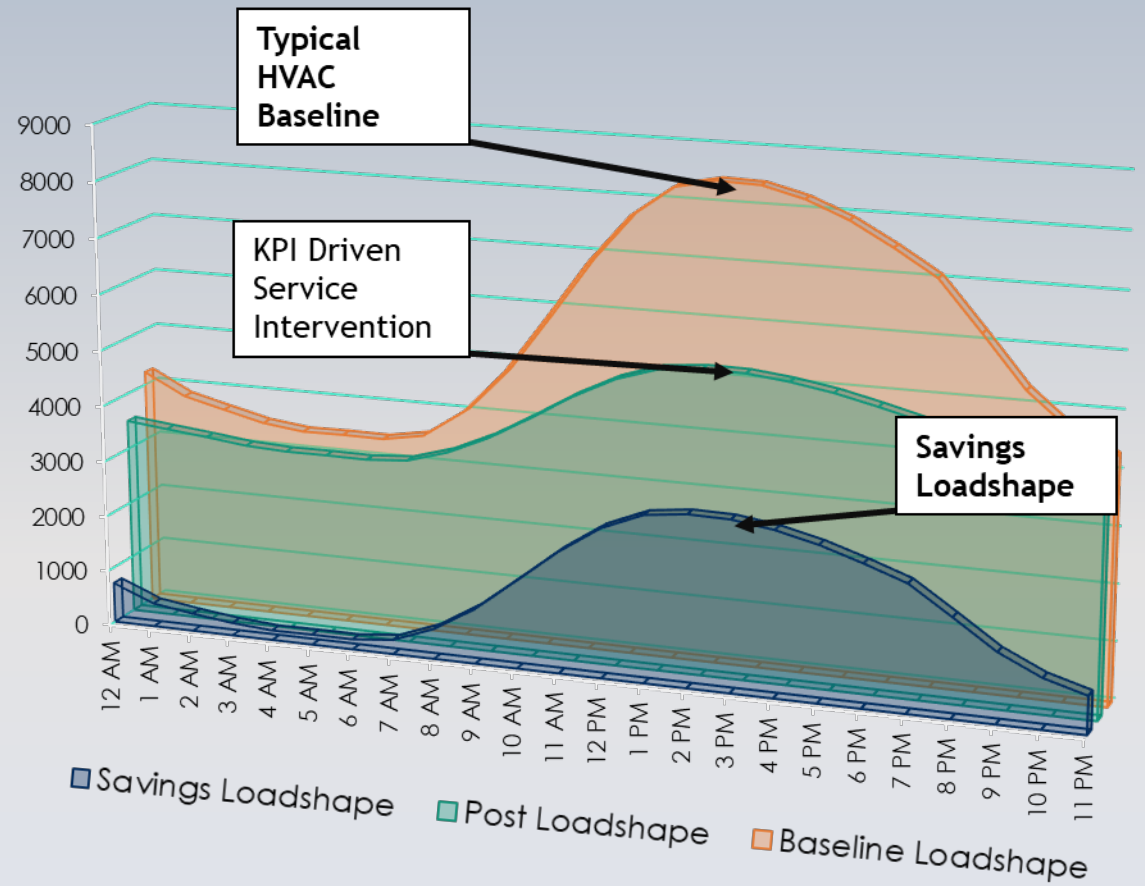
- In Figure E1 of WP: Schematic summer (July) and shoulder month (April) usage and load shape characteristics that would be expected for a customer with high savings potential from an HVAC or building shell energy efficiency program

PG&E Whitepaper (WP)
Customer Targeting for Residential Energy Efficiency Programs: Enhancing Electricity Savings at the Meter



Load Reshaping is not the goal of maintenance…But it's expected

- Projected peak day HVAC load shapes for a project in a field study conducted by NCI
- Improving capacity delivered to the space cuts runtime during peak periods, flattens load shape
- Small Office/Mixed Use building
- SOW included comprehensive duct renovation and service intervention



HVAC Load Reshaping is an intentional effort beyond the grasp of maintenance activities

The Value of Tracking Performance

As an outcome, preventive maintenance programs seek information unrelated to performance

The title, purpose and scope of ASHRAE/ACCA/ANSI Standard 180 is to *establish minimum HVAC inspection and maintenance requirements that preserve a system's ability* to achieve acceptable thermal comfort, energy efficiency, and indoor air quality in commercial buildings

A standard practice of minimum requirements to preserve maintain (something) an original or existing state establishing what is suitable and or tolerable

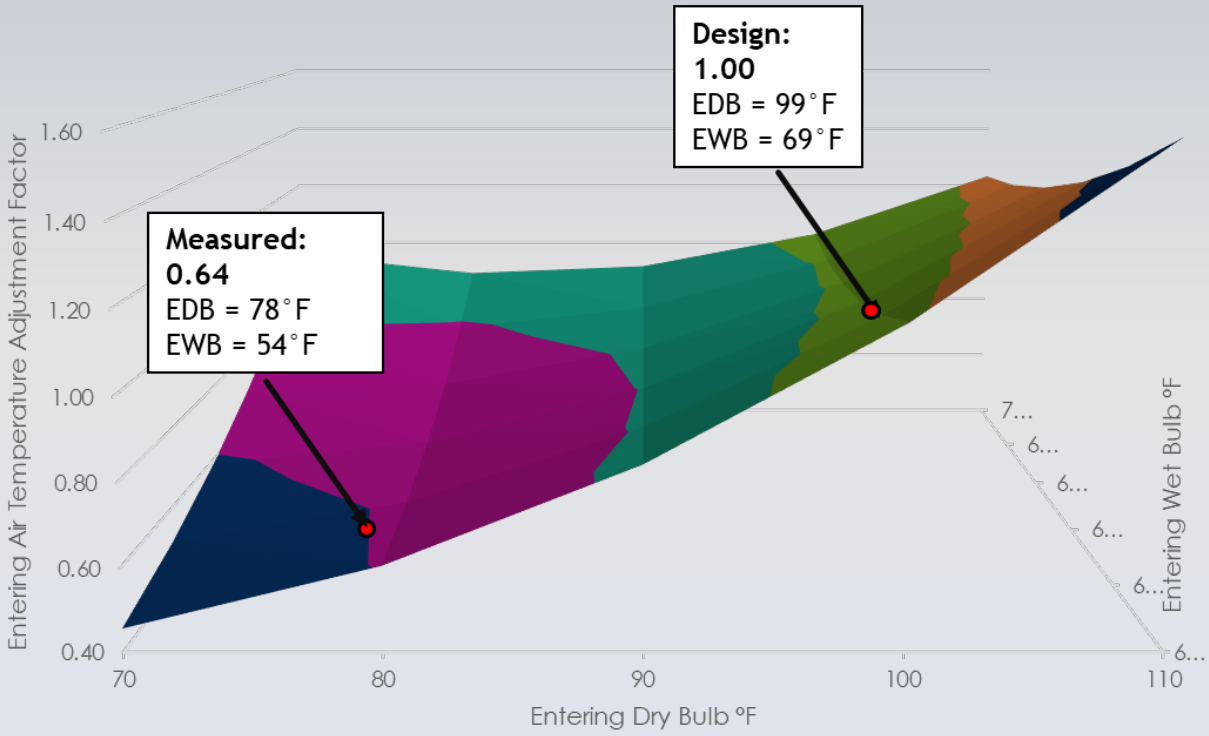
Standard 180 was not designed to bring a HVAC System to peak ("baseline") efficiency, it is tied to equipment tables for the purpose of establishing minimum HVAC inspection and maintenance requirements

Establish Reference Values- Key Performance Indicators

What should the equipment be doing?

- Need to determine expected equipment capacity at measurement conditions
- Requires coil manufacturer's performance data
- Adjust for entering conditions:
  - Current Entering Air Temperatures
  - Design Airflow for Current Fan Speed
  - Current Entering Water Temp
  - Design Water Flow Rate

Example of finding adjustment factor for entering air temperatures using mfg. performance data



Potential KPI Selections

KPI	What It Tells You
Equipment Performance Score Percent	Overall equipment performance relative to rated performance
System Performance Score Percent	Overall system performance relative to equipment rated performance
Required Airflow Percent	Actual airflow relative to design airflow
Fan Rated Static Percent	Actual static pressure relative to rated static pressure at current airflow
Supply Duct Leakage Percent	Supply duct leakage relative to supply fan airflow
Exhaust Duct Leakage Percent	Exhaust duct leakage relative to exhaust fan airflow
Air Balance Percent	Air exhausted from occupied space relative to air supplied to occupied space

Interpreting Maintenance KPI's

KPI	Tested	Interpretation
Equipment Performance Score	86%	Equipment capacity is lower than expected due to low airflow
System Performance Score	66%	Significant duct losses contributing to system inability to provide comfortable conditions
Required Supply Airflow	75%	Airflow lower than anticipated for 85% fan speed due to high static
Fan Rated Static Pressure	153%	System static higher than design intent. May be due to closed fire dampers.

Interpreting Maintenance KPI's

KPI	Tested	Interpretation
Supply Duct Leakage	18%	Significant duct leakage is present, may be contributing to inability of system to run at reduced capacity.
Return Duct Leakage	51%	Significant return leakage, may be contributing to inability of system to run at reduced capacity. Caused in part by torn flex connectors.
Building Pressure, Supply Air vs. Return Air	-122%	Building supply airflow exceeds return airflow by 33%. Excessive negative building pressure.

KPI's in Action

Scope	Impact	Benefit
Replace torn canvas joints and repair duct leaks	Reduce Supply Duct Leakage and Exhaust Duct Leakage, which will bring the System Performance Score closer to the Equipment Performance Score	Increases ability of system to provide comfort and decreases energy use
Reset and replace links on triggered shut fire dampers	Reduce % Fan Rated Static, which will allow for increase in % Required Airflow and Equipment Performance Score	Increases ability of equipment to respond to high building loads, increasing comfort and decreasing energy use on the hottest days

KPI's in Action

Scope	Impact	Benefit
Test and repair non-working control system sensors and actuators, re-evaluate control sequences, and set up for automatic operation	Allows system to respond to building loads appropriately	Increases comfort and reduces energy use year-round. Potentially reduces maintenance and equipment replacement costs by allowing equipment to operate at reduced airflows.
Rebalance airflows after changes are made	Maintains proper Air Balance	Provides a comfortable and SAFE working environment for occupants

Benefits of Measuring and Tracking System Performance

- The value of tracking performance over time with a system label
- Later we will dig deeper into each of these tests

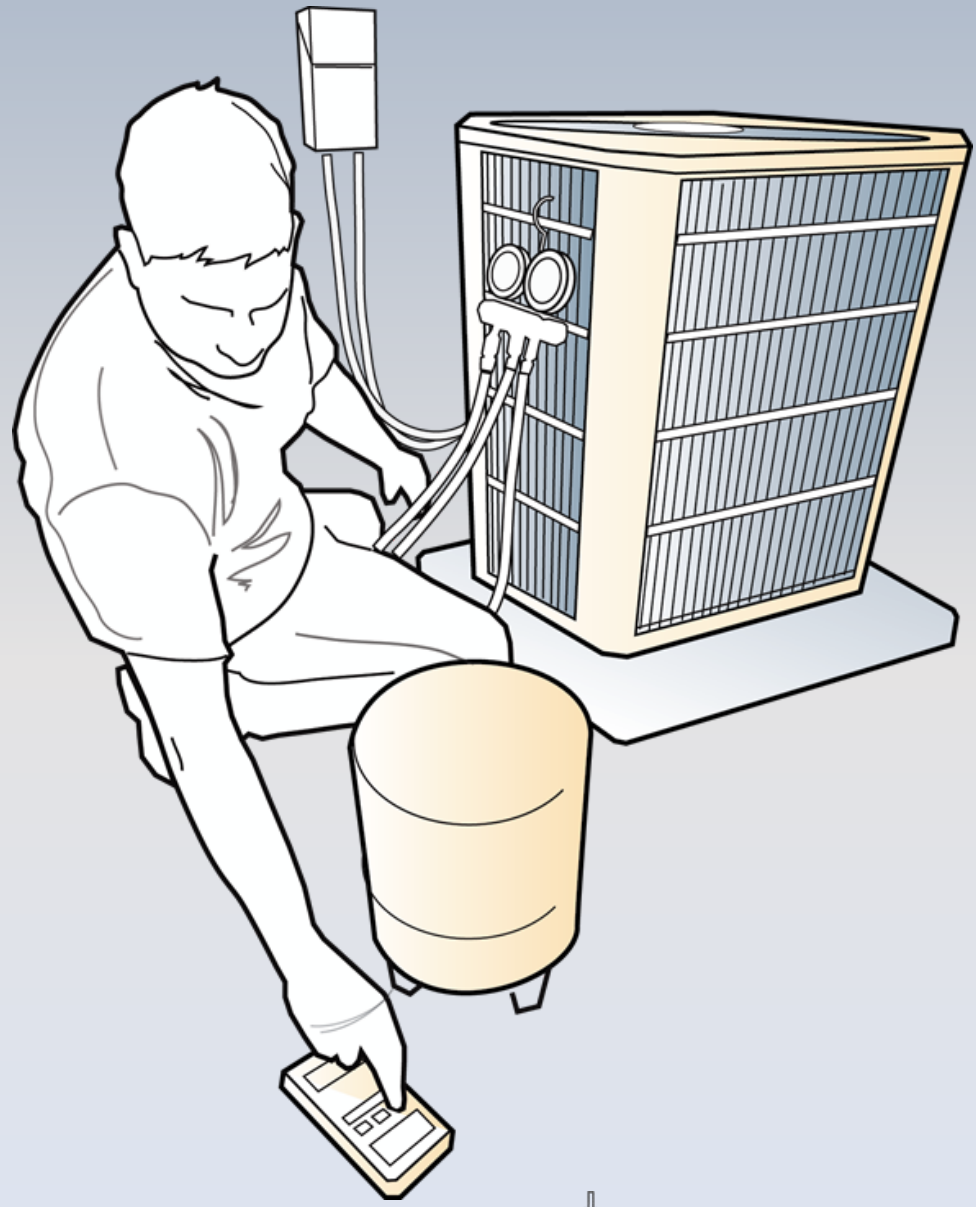
System Performance Benchmarking Record - Commercial Packaged Equipment

System Identification Number	RTU-3	Area Served	NW Wing 2nd Story	Filter Type	1" Fiberglass	Tons	10		
Date system was optimized	6/18/16	Company	Bueler Mechanical	Technician	Scott Biggs				
Rated Fan Pressure	1"	Fan design CFM	4000 CFM	Required Minimum Outside Air CFM	960 CFM				
System Performance Score	89%	Measured fan CFM	3960 CFM	Measured Minimum Outside Air CFM	874 CFM				

Date	Tech	Equip entering static pressure (a)	After filter, before coil static pressure (b)	After coil static pressure (c)	Equip exiting static pressure (d)	Calculated total external static pressure (a+d)	Calculated filter pressure drop (b-a)	Calculated coil pressure drop (c-b)	Fan RPM or fan speed setting	Econo-mizer position indicator	Ambient DB/WB temp		Equip entering DB/WB temp (e)		Equip exiting DB/WB temp (f)		Calculated equip DB/WB temp change (e-f)	
											DB	WB	DB	WB	DB	WB	DB	WB
Original Data		.28"	.48"	.86"	.38"	0.66"	0.2"	0.38"	852	3.2V	83	68	75.1	64	56.8	55.4	18.3	8.8
9/2/16	SB	.28"	.49"	.87"	.36"	0.64"	0.21"	0.38"	854	3.2V	78	-	74.2	-	54.0	-	20.2	-
1/6/17	SB	.30"	.51"	.90"	.36"	0.66"	0.21"	0.39"	851	3.2V	53	-	71.1	-	115.4	-	44.3	-
6/10/17	SB	.17"	.51"	.99"	.52"	0.69"	0.34"	0.48"	905	2.0V	91	87	82.5	73	67.2	65.1	15.3	7.4

Segment Recap – Mel Johnson

- New trends in HVAC Maintenance
- Benchmarking with test and balance Key Performance Indicators
- Energy savings expectations of maintenance
- ASHRAE Standard 180 strengths and weaknesses
- Establish maintenance KPI reference values
- Measured KPI's produce predicted maintenance opportunities
- Diagnose and solve maintenance problems
- **Please visit us in Booth 7478**



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Rob Falke Presentation Preview

Solve Hidden Maintenance Issues Using Testing and Balancing

- What's included in a typical maintenance agreement … and what's missing
- Static pressure profile
- Changes to airflow in equipment
- Changes to airflow in duct system
- Duct system temperature loss
- Room airflow changes
- Recap of discovering hidden maintenance issues

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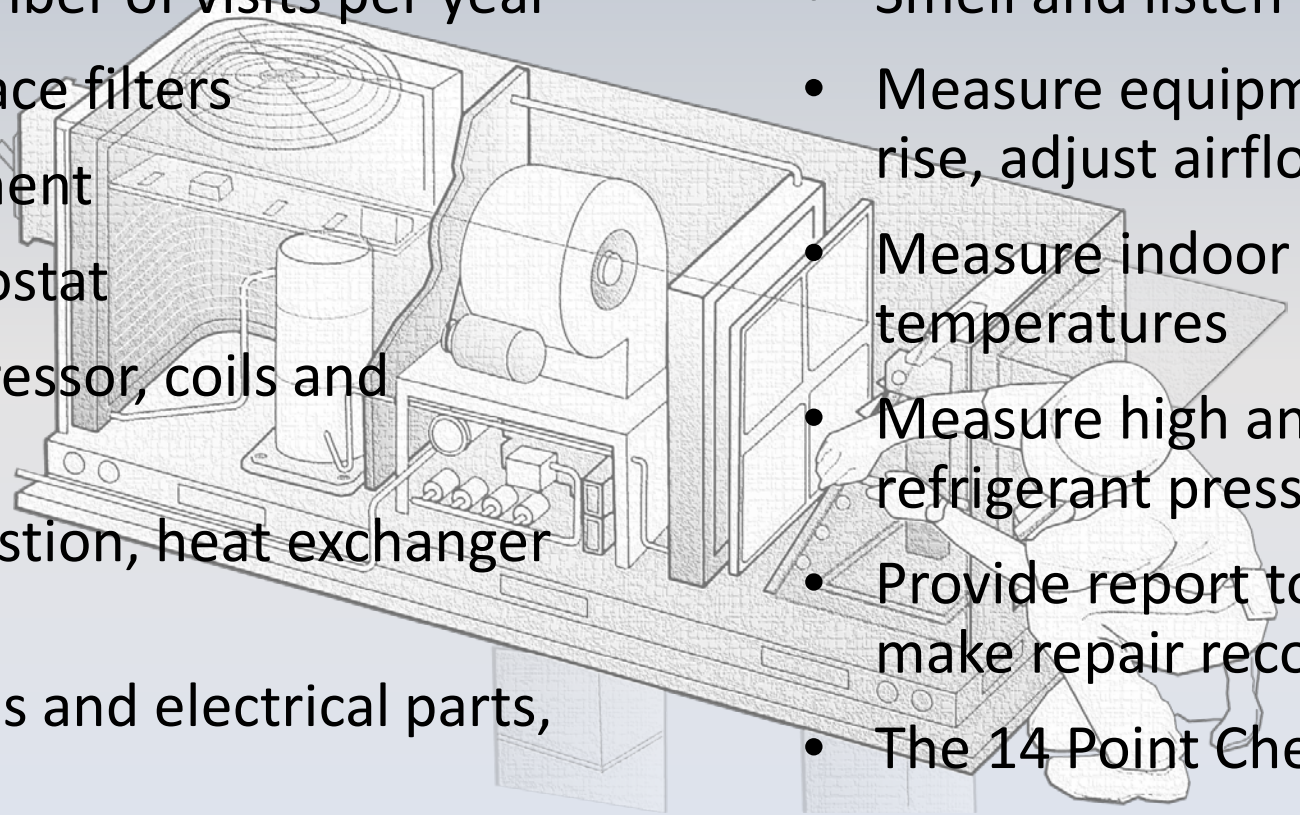
What's Included in a Typical HVAC Service Agreement

As summarized from equipment manufacturer recommendations

- Price and number of visits per year
- Clean or replace filters
- Clean equipment
- Check thermostat
- Check, compressor, coils and condensate
- Check combustion, heat exchanger and flue
- Check controls and electrical parts, check voltage
- Check blower assembly and belts

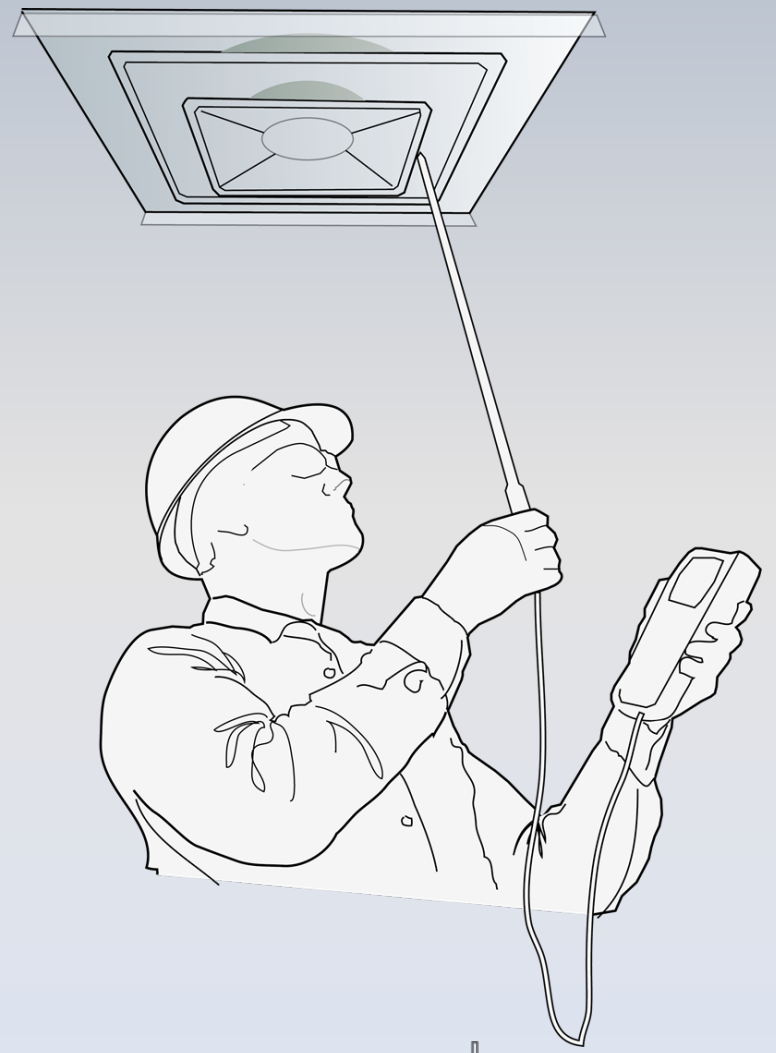


- Smell and listen
- Measure equipment temperature rise, adjust airflow
- Measure indoor and outdoor temperatures
- Measure high and low side refrigerant pressures
- Provide report to customer and make repair recommendations
- The 14 Point Checklist

What a Typical Maintenance Agreement Overlooks

Hidden airflow and performance changes in the system

1. Fan total external static pressure changes
2. Changes in pressure over system components
3. Fan speed or RPM changes
4. Fan airflow changes
5. Air distribution system changes
6. Economizer, duct leakage and grille airflow changes



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Let's take a deeper look into this system maintenance label

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Static Pressure Profile

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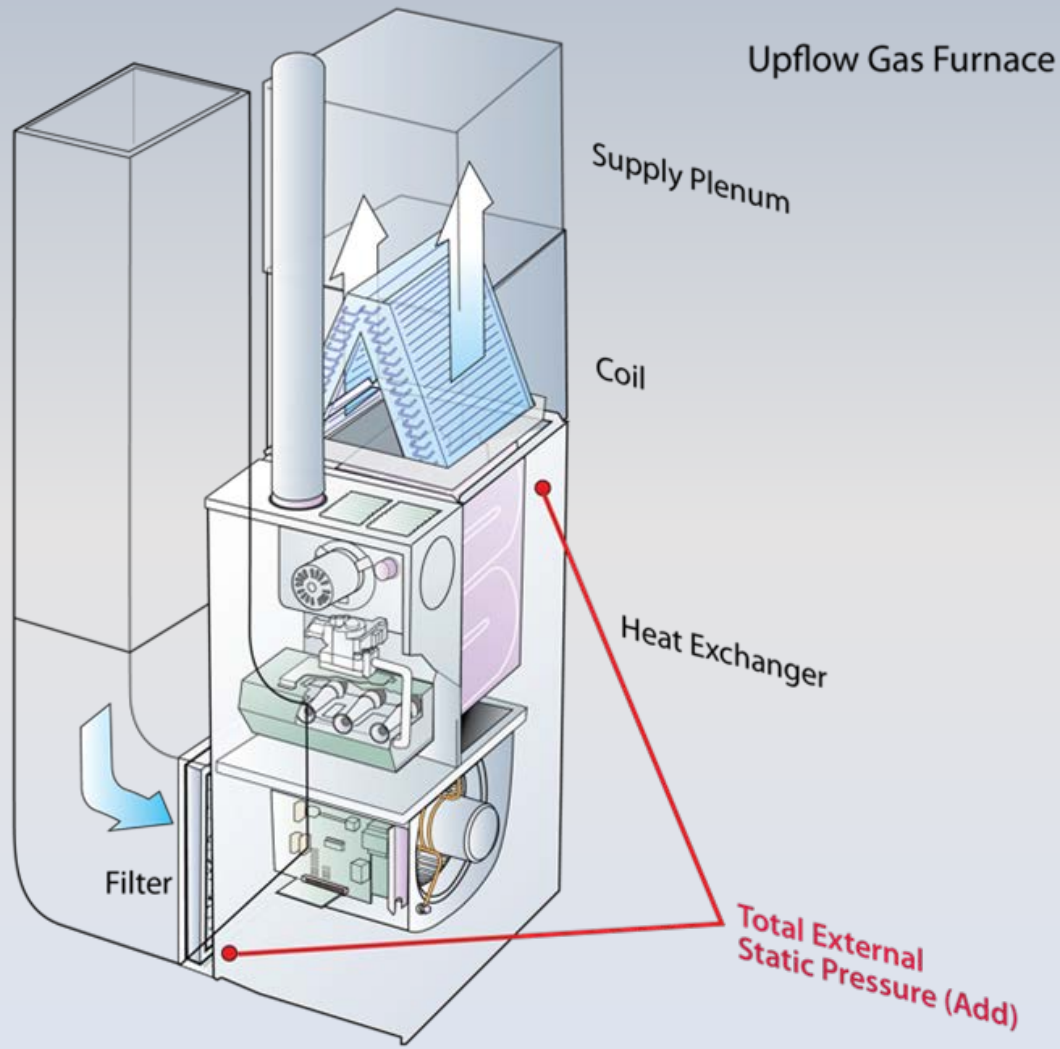
Total External Static Pressure

If pressure changes, the system has changed

- Measure equipment inlet pressure
- Measure equipment outlet pressure
- Add the two pressure together to find total external static pressure
- Compare measured total external static pressure to nameplate pressure. More than 10% high, chances of excellent airflow are poor.

What could cause high total external static pressure?

Do any of you include total external static pressure in your maintenance agreements?

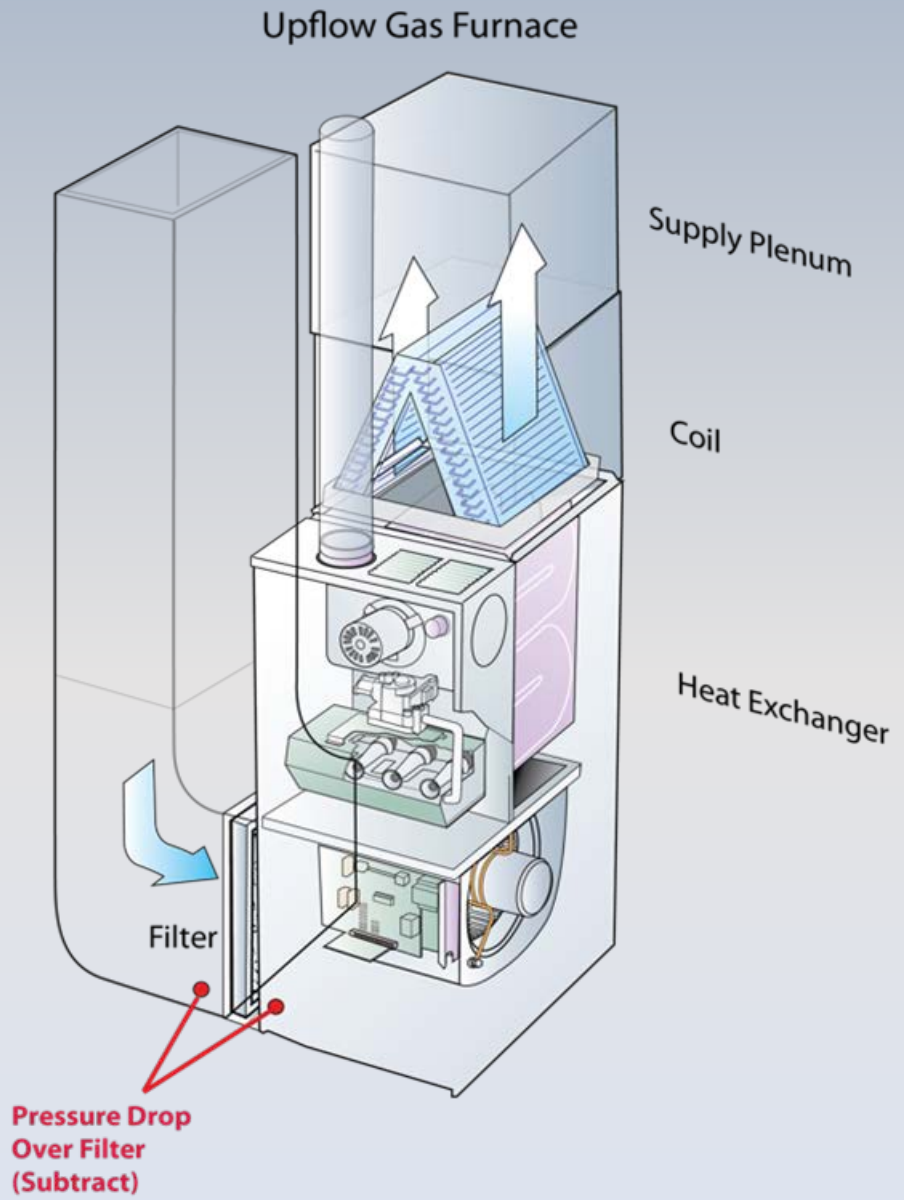


Air Filter Pressure Drop

- Measure before and after the filter
- Subtract the two pressures to find filter pressure drop
- Rule of Thumb - Typically filter pressure drop should not exceed 20% of fan rated pressure

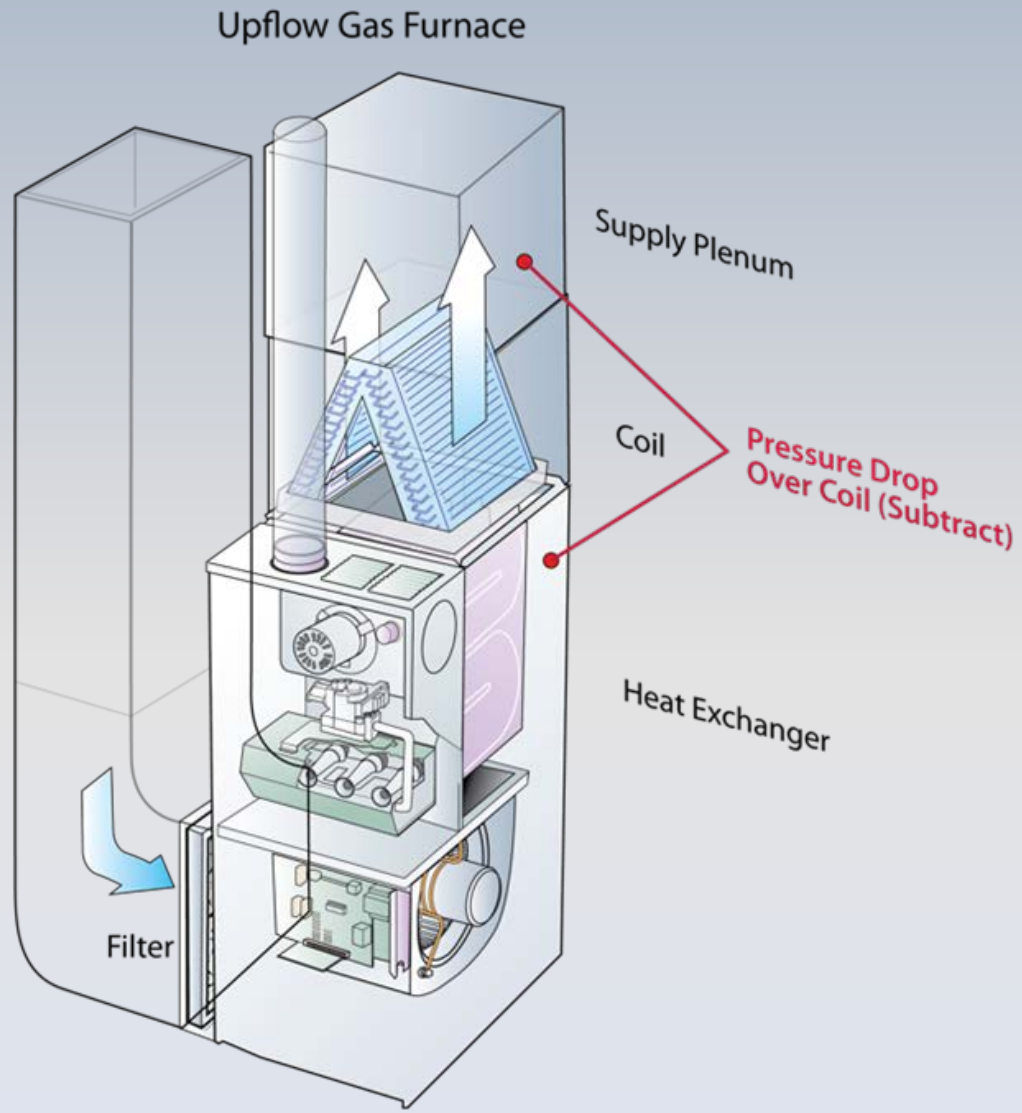
What could cause high filter resistance to airflow?

What maintenance repairs have you done to lower filter pressure drop?



Measure Coil Air Pressure Changes

- **Measure before and after** the external cooling coil
- **Subtract the two pressures** to find coil pressure drop
- Rule of Thumb - Typically cooling coil pressure drop **should not exceed 40%** of fan rated pressure



What could cause increase coil resistance to airflow?

What action would **lower coil pressure drop**?

Any good maintenance experiences?

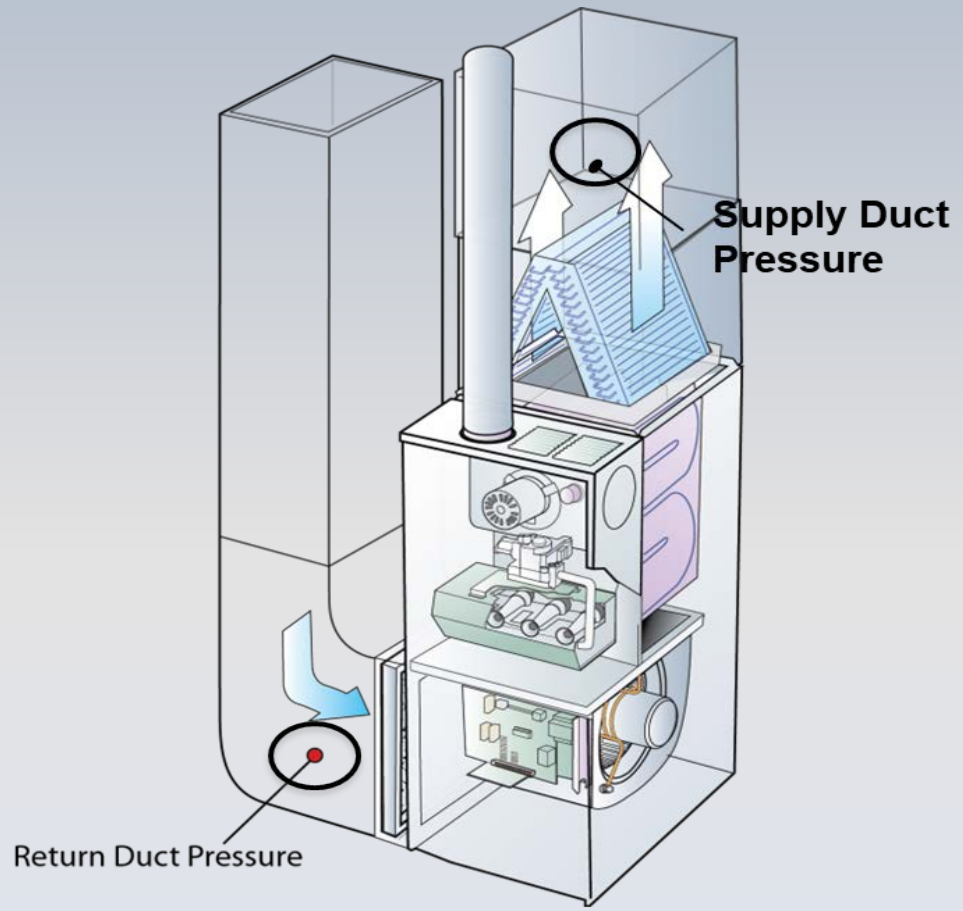
Duct System Pressures

Return - Measure static pressure at a single point before the equipment to find the return duct pressure.

Supply - Measure static pressure at a single point after the equipment to find the supply duct pressure.

Each duct system pressure **should not exceed 20% of fan rated pressure**

Can **reveal restrictions** such as a duct fitting, loose duct liner, or undersized duct.



Track Fan RPM and Economizer Position Indicator

If fan RPM changes, fan airflow changes

- Fan speed changes can be caused by:
  - Pulley adjustments or belt slippage
  - VFD setting changes
  - Responses to system pressure changes in variable speed fans

If economizer louvers change position, economizer airflow changes

- Economizer louver positions can be changed by:
  - Responses to control signals (Test in minimum position)
  - Damage to louver, linkages or damaged sensors
  - Control setting changes

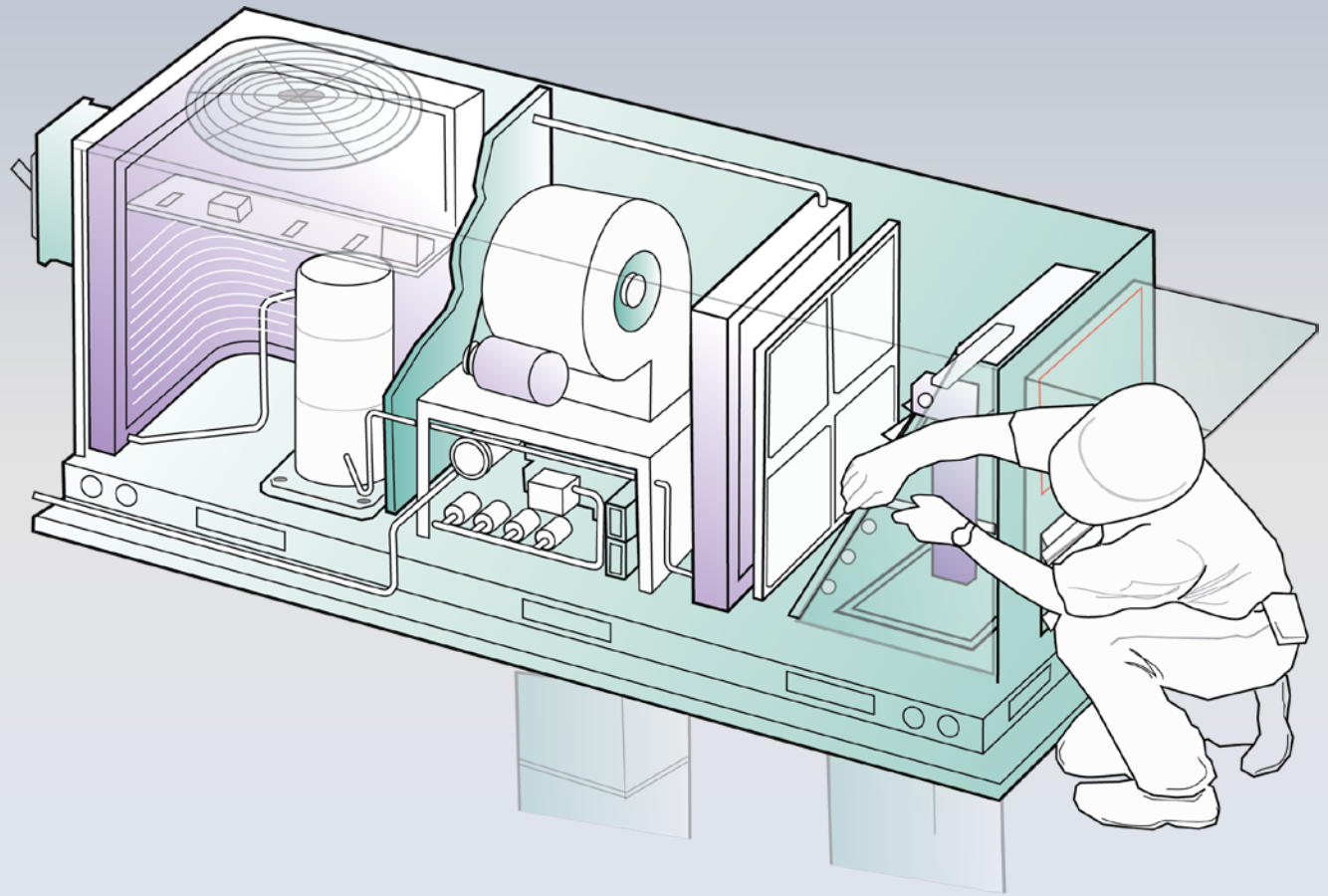
Fan RPM or fan speed setting	Econo-mizer position indicator
852	*3.2V*
854	*3.2V*
851	*3.2V*
905	*2.0V*

Temperature Changes Tell a Story – Read it!

Ambient DB/WB temp		Equip entering DB/WB temp (e)		Equip exiting DB/WB temp (f)		Calculated equip DB/WB temp change (e-f)	
DB	WB	DB	WB	DB	WB	DB	WB
83	68	75.1	64	56.8	55.4	18.3	8.8
78	-	74.2	-	54.0	-	20.2	-
53	-	71.1	-	115.4	-	44.3	-
91	87	82.5	73	67.2	65.1	15.3	7.4

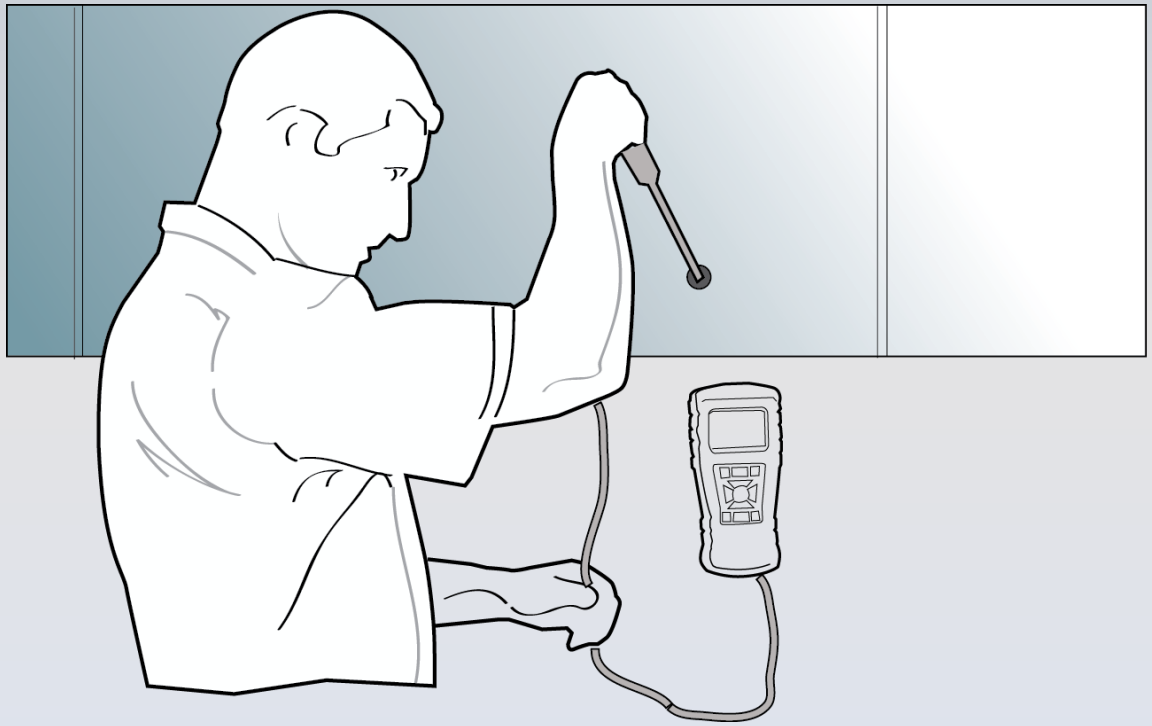
- If temperature changes, **system capacity** may change
- System temperatures are affected by **outdoor temperatures**
- Can indicate **refrigeration or combustion** circuit changes
- May indicate **airflow changes**
- Often indicate **changes in the air distribution** system.

Good Maintenance Detects Equipment Airflow Changes



- Restrictive filters
- Loaded coils
- Although difficult to find – restrictive curbs
- Economizer airflow changes
- Fan speed changes
- Control settings

Changes to Airflow in Duct Systems



Causes Include

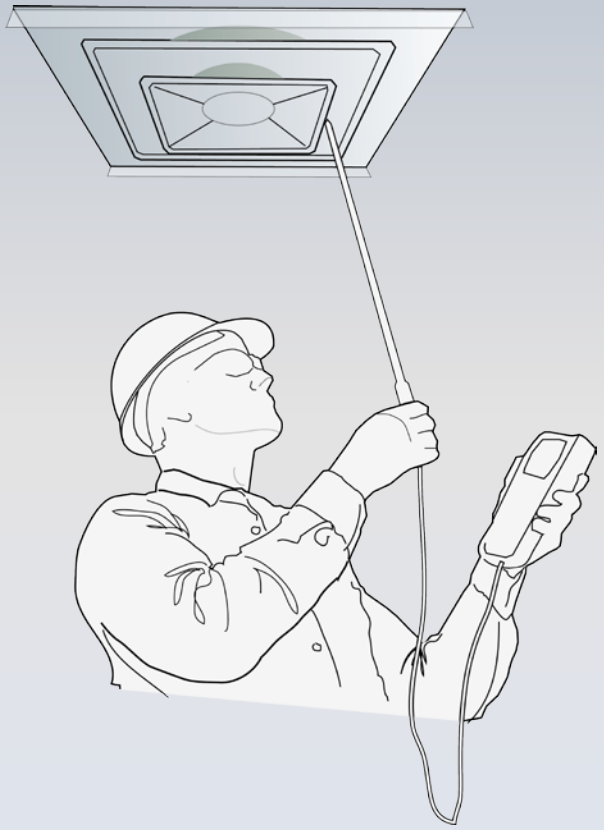
- New (or old) duct leakage
- Duct damage
- Duct and fitting suspension
- Duct liner falling off
- Hardware breakage
- Dampers closed or open
- Racoons…

Duct Temperature Loss Testing

Supply Duct Temperature Loss

1. Measure and record db air temperature **where air exits the equipment**.
2. Measure and record db air temperature where air **enters the occupied space**.
3. Subtract the two temperatures to find duct loss.

Cooling Example: 54.2F – 59.2F = 5.0 degree loss through the supply ducts



Return Duct Temperature Loss

1. Measure and record db air temperature **where air leaves the occupied space**.
2. Measure and record db air temperature **where air enters the equipment**
3. **Subtract the two** temperatures for find duct loss.

Cooling Example: 74.6F – 64.2F = 10.0 degree loss through the return ducts.

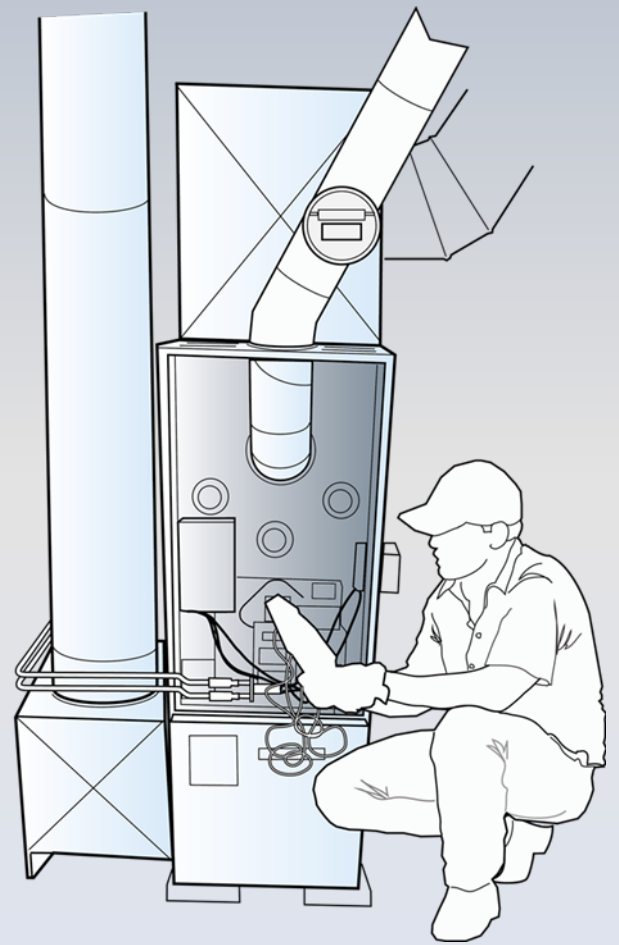
Room Airflow Changes as an Add-on Maintenance Service

While Most Maintenance Agreements Focus on the Equipment. Room Airflow takes Maintenance to Another Level.

- Find the project plans to **determine design airflow.** Or, calculate required room airflow
- **Measure room airflow** using a commercial balancing hood or by an airflow traverse
- **Compare** design to actual airflow

Recap - Solve Hidden Maintenance Issues Using Testing and Balancing

- **New trends in HVAC Maintenance** with test and balance KPI's
- Discussed the **energy savings expectations** of maintenance
- Measured KPI's produce **predicted maintenance opportunities**
- What's included in a **typical maintenance agreement**…and what's missing
- Consider adding **static pressure profiles**
- **Changes to airflow** in equipment and duct systems
- **Duct system** temperature loss
- Move to the air distribution side with your maintenance agreements



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